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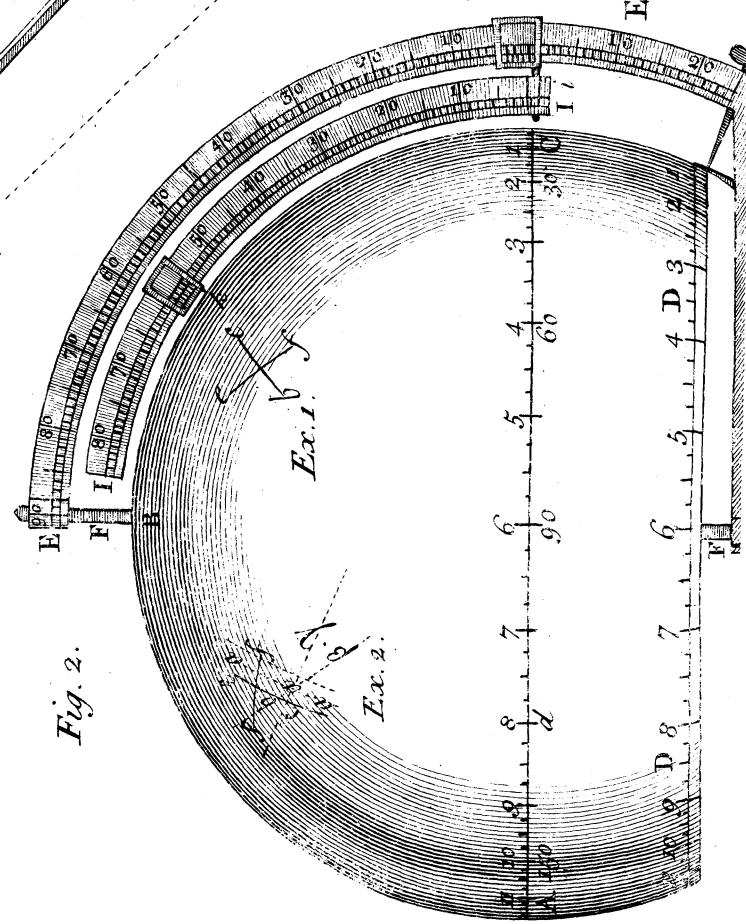
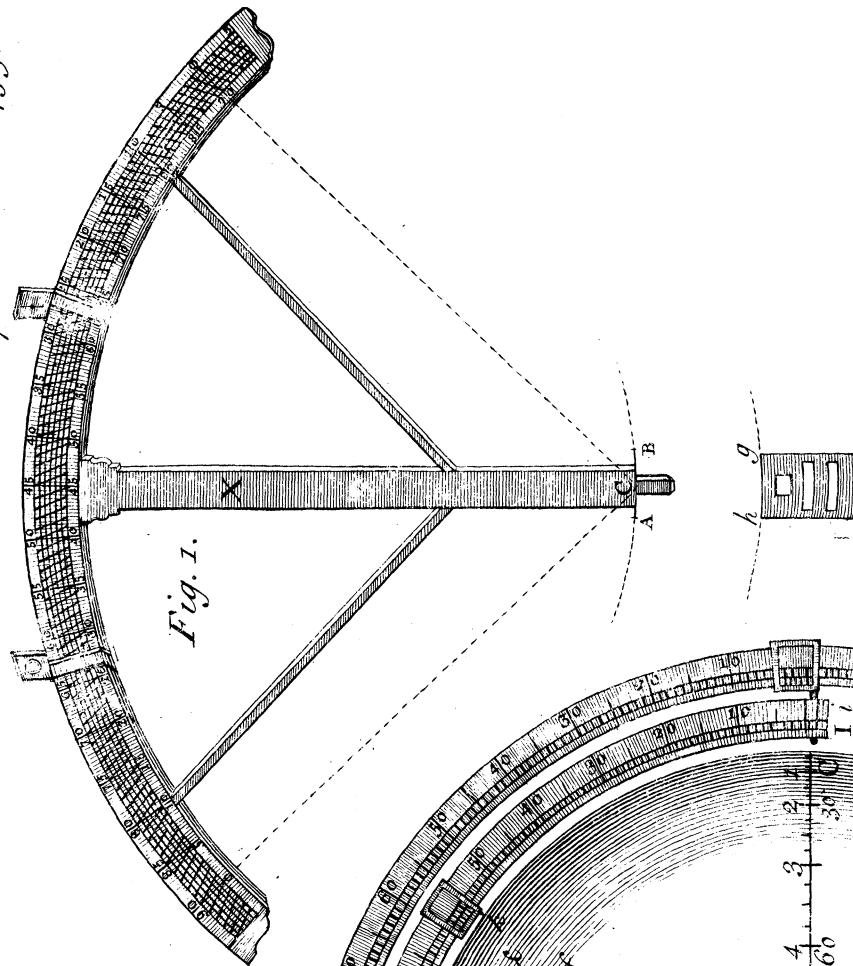
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III. *An Account of Mr. Thomas Godfrey's Improvement of Davis's Quadrant, transferred to the Mariner's-Bow, communicated to the Royal Society, by Mr. J. Logan.*

B eing inform'd that this Improvement, proposed by *Thomas Godfrey* of this Place, for observing the Sun's Altitude at Sea, with more Ease and Expedition than is practicable by the common Instruments in use for that purpose, was last Winter laid before the *Royal Society*, in his own Description of it ; and that some Gentlemen wish'd to see the Benefit intended by it more fully and clearly explained: I, who have here the Opportunity of knowing the Author's Thoughts on such Subjects, being perswaded in my Judgment that if the Instrument, as he proposes it, be brought into Practice, it will in many Cases be of great service to Navigation, have therefore thought it proper to draw up a more full Account of it, than the Author himself has given, with the Advantages attending it ; which if approved of by better Judgments, to whom what I offer is entirely submitted, 'tis hoped the Use of it will be recommended and further encouraged, as also the Author. The Rise of the Improvement with its Conveniencies, as also a Description of it, are as follows.

Tho. Godfrey, having under the greatest Disadvantages (as I observed in my first Letter to Dr. *Halley*, giving an Account of his Invention of the Reflecting Instrument) made himself Master of the Principles of Astronomy and Optics, as well as other

Parts of Mathematical Science, applied his Thoughts to consider the Instruments used in that most momentous Part of Business, Navigation. He saw that on the Knowledge of the Latitude and Longitude of the Place a Ship is in, the Lives of thousands of useful Subjects, as well as valuable Cargoes, continually depend ; that for finding the first of these, certain and easy Methods are furnish'd by Nature, if Observations be duly made: But *Davis's Quadrant*, the Instrument generally used by British Navigators, (tho' seldom by Foreigners) he perceived was attended with this Inconveniency, that the Observer must bring the Shade or Spot of Light from the Sun, and the Rays from the Horizon, to coincide exactly on the fiducial Edge of the horizontal Vane : That tho' this can be done in moderate Weather and Seas with a clear Sky, and when the Sun is not too high, without any great Difficulty ; yet in other Cases it requires more Accuracy than can in some Junctures possibly be applied, and more Time than can be allowed for it. In *European Latitudes*, or to those nearer the Northern Tropick, when the Sun is in the Southern Signs, and near the Meridian, he rises and falls but slowly : Yet in Voyages to the *East* and *West-Indies*, of which very many, especially to the latter, are made, he is at Noon, often and for many Days together, in or near the Zenith, and when approaching to, or leaving it, he rises and falls, when he has Declination, faster than even at the Horizon ; for it is well known to Persons acquainted with the Sphere, that when his diurnal Course takes the Zenith, he there rises and falls a whole Degree or 60 Minutes, in the Space of four Minutes

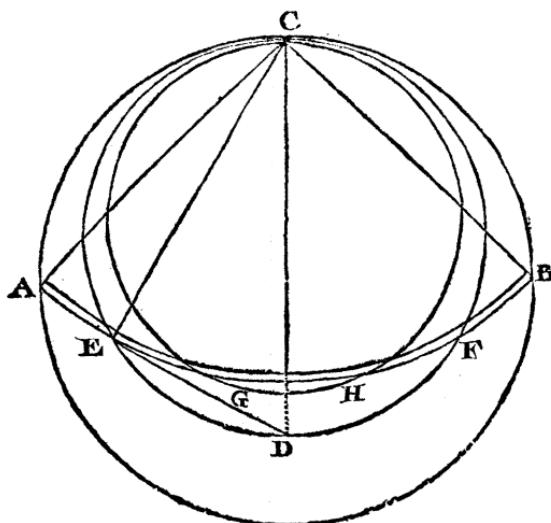
Minutes of Time ; so that the Observer has but one Minute, to come within 15 Minutes of the Truth in his Latitude : While in a middle Altitude, as 45 Deg. he is at Noon above 5 Minutes and a half in Time, in rising or falling one single Minute of Space, the Odds between which is more than 80 to 1. And yet, perhaps, no Parts of the World require more Exactnes in taking the Latitude than is necessary in Voyages to the *West-Indies* : For it is owing to the Difficulty of it, that Vessels have so frequently miss'd the Island of *Barbados*, and when got to the Leeward of it have been obliged to run down a thousand Miles further to *Jamaica*, from whence they can scarce work up again in the Spice of many Weeks, against the constant Trade-winds, and therefore generally decline to try for, or attempt it.

But farther, as the Latitude cannot be found by any other Method, than by the Sun or a Star on the Meridian : In a cloudy Sky, when the Sun can but now and then be seen, and only between the Openings of the Clouds for very short Intervals, which those who use the Sea know frequently happens : As also in high tempestuous Seas, when tho' the Sun should appear, the Observer can scarce by any Means hold his Feet ; it would certainly be of vast Advantage to have an Instrument by which an Observation could also be, as it were, snatched or taken in much less Time, than is generally required in the Use of the common Quadrant.

Tho. Godfrey therefore considering this, applied himself to find out some Contrivance by which the Necessity of bringing the Rays from the Sun, and those from the Horizon to coincide (which is the most difficult part of the Work) on one particular Point or Line from the Centre, might be removed. In order to which he consider'd, that by the 21. 3^d *Elem. of Eucl.* all Angles at the Periphery of a Circle, subtended by the same Segment within it are equal, on whatever part of the Circumference the angular Point falls ; and therefore, if instead of a Quadrant, a Semicircle were graduated into 90 Degrees only, accounting every two Degrees but one ; this would effectually answer : For then, if an Arch of the same Circle were placed at the End of the Diameter of the Instrument, every Part of that opposite Arch would equally serve for taking the Coincidence of the Rays above-mentioned. But such an Instrument would manifestly be attended with great Inconveniencies ; for it would in great Altitudes be much more unmanageable, and the Vanes could not be framed to stand, as they always ought, perpendicular to the Rays. He therefore further resolved to try whether a Curve could not be found to be placed at the Centre of a Quadrant, which would, at least for a Length sufficient to catch the Coincidence of the Rays, with Ease fully answer the Intention.

A Curve that in all the Parts of it would in geometrical strictness effect this, cannot be in Nature, any more than that one and the same Point can be found for a Centre to different Circles, which are not concentric. It is certain that every Arch on the Limb may have a Circle that will pass through the

the Center, and be a Locus or geometrical Place for the Angle made by that Arch to fall on: but then every Arch has a different one from all others; as in the Figure. Let ABC be the Quadrant, and AB , EF , GH be taken as Arches of it: Circles drawn through each two of these respectively, and through the Center C as a third Point, will manifestly be such Loci or Places: For every Pair of these



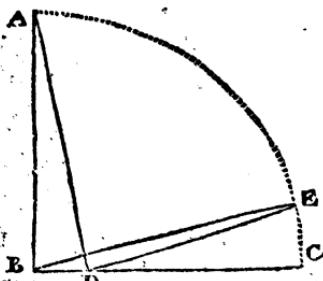
Points stand in a Segment of their own Circle, as well as on a Segment of the Quadrant; and therefore by the cited 21. 3^d *Elem.* the Angles standing on these first Segments will every where be equal at the Periphery of their respective Circles, and their Radius will always be equal to half the Secant of half the Arch on the Quadrant. For in the Circle $CEDF$ (for Instance) the Angle CED is right, because 'tis in a Semicircle, CE is the Radius of the Quadrant,

ED

ED the Tangent of the Angle DCE = the Arch EF, and GD is the Secant of the same = the Diameter of the Circle CEDF, and therefore its Radius is half that Secant.

Now from the Figure 'tis plain, that in very small Arches the Radius of their circular Place will be half the Radius of the Quadrant, that is, putting this Radius = 10, the other will be 5. And the Radius for the Arch of 90, the highest to be used on the Quadrant will be the Square Root of half the Square of the Radius = Sine of 45 Degrees = 7.071, and the Arches at the Center drawn by these two *Radij* are the Extreams, the Medium of which is 6.0355. And if a circular Arch be drawn with this Radius $\frac{1}{10}$ th Part of the Length of it, that is, in an Instrument of 20 Inches Radius, the Length of one Inch on each Side of the Center affording two Inches in the whole, to catch the Coincidence of the Rays on, which must be own'd is abundantly sufficient, the Error at the greatest Variation of the Arches, and at the Extremity of these 2 Inches, will not much exceed one Minute.

But in fixing the Curvature or Radius of this Central Arch, something farther than a Medium between the Extreams in the Radius is to be considered : For in small Arches the Variation is very small, but in greater it equally encreases, as in the Figure where it appears, the Difference between the Angles ABC to ADC is much greater than the Difference between



tween EBC and EDC, though both are subtended by the same Line BD: for their Differences are the Angles BAD and BED. Therefore this Inequality was likewise to be considered; and compounding both together, *Tho. Godfrey* pitched on the Ratio of 7 to 11, for the Radius of the Curve to the Radius of the Instrument, which is 6.3636 to 10. But on further Adviseiment he now concludes on $6\frac{4}{5}$; and a Curve of this Radius of an Inch on each Side of the Center to an Instrument of 20 Inches Radius or of $\frac{1}{20}$ th of the Radius, whatever it be, will in no Case whatever, as he has himself carefully computed it, produce an Error of above 57 Seconds; and 'tis very well known that Navigators (as they very safely may) in their Voyages intirely slight a Difference of one Minute in Latitude.

This Radius is the true one for the circular Place to an Arch of $77^{\circ} 15'$, and the Variation from it is nearly as great at 90 Degrees as at any Arch below it, the greatest below being at about 44 Degrees, which is owing to the Differences expressed by the last Figure above, and not to those of the Curvatures or circular Places. Yet this Variation of 57 Seconds arises only when the Spot or Coincidence falls at the Extremity of the horizontal Sight or Vane, or a whole Inch (in an Instrument of 20 Inches Radius) from the Center, and then only in the Altitudes or Arches of about 44 or 90 Degrees. And in these, at the Distance of half an Inch from the Center, the Variation is but $\frac{1}{4}$ so much, *viz.* about $14''$; and at $\frac{1}{4}$ of an Inch, not $4''$; at the Center tis precisely true. Therefore as an Observation may be taken with it in one fourth of the Time, that *Davis's Quadrant*, on which

which three Things must be brought to meet, in a general way requires: I say, considering this, and the vast Importance of such Dispatch, in the Case of great Altitudes, or of tempestuous Seas, or beclouded Skies, tis presumed the Instrument thus made will be judged preferable to all others of the kind yet known. Some Masters of Vessels, who sail from hence to the *West-Indies*, have got of them made as well as they can be done here; and have found so great an Advantage in the Facility and in the ready Use of them, in those Southerly Latitudes, that they reject all others. And it can scarce be doubted, but when the Instrument becomes more generally known, it may upon the *Royal Society's* Approbation, if the Thing appear worthy of it, more universally obtain in Practice.

'Tis now four Years since *Tho. Godfrey* hit on this Improvement; for his Account of it, laid before the Society last Winter, in which he mentions two Years, was wrote in 1732. And in the same Year, 1730, after he was satisfied in this, he applied himself to think of the other, *viz.* the reflecting Instrument by Speculums, for a help in the Case of Longitude, though 'tis also useful in taking Altitudes, and one of these, as has been abundantly proved by the Maker, and those who had it with them, was taken to Sea, and there used in observing the Latitude, the Winter of that Year, and brought back again hither before the End of *February*, 1731, and was in my keeping for some Months immediately after. It was unhappy indeed, that having it in my Power, seeing he had no Acquaintance nor Knowledge of Persons there, that I transmitten not an Account of it sooner: But I had

had other Affairs of more Importance to me : And it was owing to an Accident which gave me some Uneasiness, *viz.* his attempting to publish some Account of it in Print here, that I did it at that Time, *viz.* in *May 1732*, when I transmitted it to Dr. *Halley* ; to whom I made not the least Doubt but the Invention would appear entirely New. This, on my part, was all the Merit I had to claim, nor did I then, or now assume any other, in either of these Instruments. I only wish that the ingenious Inventor himself might by some means be taken Notice of, in a Manner that might be of real Advantage to him.

There needs not, I suppose, much more of a Description of the Instrument than has been given : I shall only say, the Bow had best be an Arch of about 100 Degrees, well graduated, and numbered both ways ; the Radius of 20 or 24 Inches ; the Curve at the Center to be $\frac{1}{20}$ th of the Radius on each Side, that is, $\frac{1}{10}$ th of it in the whole ; the Radius of that Curve $\frac{1}{200}$ Parts of the Radius of the Instrument ; that the Glass for the Solar Vane should not be less, but rather larger, than a silver Shilling, with its Vertex most exactly set. And that the utmost Care be taken to place the Middle of the Curve at the Centre exactly perpendicular to the Line or Radius of 45 Degrees. As the Observer must also take Care that the two Vanes on the Limb be kept nearly equidistant from that Degree ; to which I shall only add, that it may be best to give the horizontal Vane only one Aperture, and not two. The rest I suppose may be left to the Workmen. Thus doubting I have already been too prolix on the Subject, to which nothing but a sincere Inclination to promote

any thing that might contribute to a publick Benefit, and to do some justice to Merit, could induce me, I shall only request that what I have here offered may be construed by that Intention.

Philad. 28th of
June, 1734.

J. LOGAN.

Note, That the Radius of the Quadrant being divided into 20 equal Parts, the Center x (in *Fig. 1.*) of the Curvature of the Horizontal Vane (A B) must be $12 \frac{8}{10}$ of those Parts from the Center (C) of the Quadrant. The Breadth (A B or $g\ b$) of that Vane should be $\frac{1}{10}$ of the whole Radius, that is, $\frac{1}{20}$ on each Side of the Center (C).

IV. The Description and Use of an Instrument for taking the Latitude of a Place at any time of the Day; by Mr. Richard Graham, F. R. S.

THE necessity of finding the Latitude, a Ship is in, is too well known to be insisted on: Frequent opportunities of observing the Latitude must consequently